Int J Life Cycle Assess (2014) 19:962–967
DOI 10.1007/s11367-014-0703-8

UNEP/SETAC CORNER

Global guidance on environmental life cycle impact assessment indicators: findings of the scoping phase

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Received: 7 January 2014 / Accepted: 9 January 2014 / Published online: 24 January 2014

1 Introduction

1.1 Global guidance on LCIA indicators

During Phase 1 (2002–2007) of the Life Cycle Initiative, work was intensively conducted on developing an initial framework (Jolliet et al. 2004) and contributed to the development of first-stage harmonized LCIA tools such as the USEtox model for life cycle toxicity impact assessment (Hauschild et al. 2008). Activities in Phase 2 (2007–2012) similarly addressed carbon footprint, water use and land use impact assessment throughout the life cycle (Bayart et al. 2010; Koellner et al. 2013; Kounina et al. 2013). In parallel, and also building on these activities, a number of other initiatives have been advancing proposals and dissemination of impact assessment indicators in various continents (Hauschild et al. 2013; Murakami et al.

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2012). With the globalization of our economy, there has been a steadily growing need to create a worldwide consensus set of environmental impact category indicators embedded in a consistent methodological framework. Such a set is expected to be used in particular in environmental product information schemes, benchmarking in industry sectors, corporate reporting by companies, intergovernmental and/or national environmental policies and common LCA work commissioned by governments and companies.

To address this need, Phase 3 of the UNEP-SETAC Life Cycle Initiative (2012–2017) has launched a flagship project to provide global guidance and build consensus on environmental LCIA indicators (see http://www.lifecycleinitiative.org/ under the Phase 3 activities for the full list of projects). This global process will start with a limited number of life cycle impact category indicators developed within a consistent framework. It will also provide guidance on how to best establish additional relevant impact category indicators. The project has been taken up by UNEP and SETAC in its Rio+20 Voluntary Commitments (UNCSD 2012). An initial scoping workshop took place in Yokohama, Japan, in November 2012 to launch the process.

1.2 Expected outcomes of the LCIA guidance flagship project

The deliverables will include a global guidance publication with a supporting web-based system that contains the finally selected LCA-based environmental impact category indicators and characterization factors (for various regions), which will be available for viewing and download. Outputs may also include guidance on how to best establish a particular regional impact category indicator in the event global consensus on such characterization factors cannot be achieved. It will also suggest a research agenda for areas like biotic or mineral resources, in which further developments are needed. Moreover, the Initiative will disseminate this work and support its implementation in public and private sectors. It will later facilitate follow-up activities to ensure that the related research agenda is being implemented.

2 Scoping the LCIA guidance flagship project

2.1 The Glasgow scoping workshop

A second scoping workshop was conducted in Glasgow, Scotland, on 16–17 May 2013 to establish a tentative short list of four to eight impact category indicators to address during two sequential periods of consensus building of this project for global LCIA guidance. The workshop initiated the process by defining specific work plans for each individual impact category, identifying experts to be involved and defining a common process towards consensus within and across impact categories.

The workshop involved 40 in-person and 25 online attendees from more than 20 nations for the initial, open invitation session. Twenty-five experts participated in the second-day session dedicated to the identification of key consensus issues and the development of a preliminary work plan for the selected impact categories. This short paper summarizes the main findings and scoping decisions of the workshop, describes the preliminary analyses and pre-selection of impact categories and identifies cross-cutting issues, work process and governance towards establishing consensus on category indicators. It also defines the next steps and deliverables, which will foster more extensive involvement of experts and stakeholders worldwide.

2.2 Analysis and pre-selection of impact categories suited for consensus

Prior to the workshop, a preliminary evaluation was conducted by the workshop steering committee to analyse needs and state-of-the art approaches for LCIA impact categories according to the following five criteria: (a) *Environmental relevance*—importance to overall environmental impacts, (b) *scientific validity*—how mature is the science, to which extent are peer-reviewed publications available, (c) *potential for consensus*—what is the level of agreement among researchers and users, (d) *stakeholder needs*—what are the main environmental issues to be taken into account in decision-making processes and in product information and (e) *applicability*—to which extent are factors available and easy to use for common life cycle inventory flows and LCI databases

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worldwide. This evaluation of the state-of-the-art in LCIA and the slides presented at the Glasgow workshop can be downloaded at http://www.lifecycleinitiative.org/ under the Phase 3 activities. Based on seminal global environmental assessments (e.g. the environmental burden of disease assessment (Lim et al. 2012), the Millennium Ecosystem Assessment (Powledge 2006) or the analysis of the safe operating space for humanity (Rockström et al. 2009) and on more LCA-specific sources like the report of the International Resource Panel (UNEP 2010), the main analyses lead to the following statements:

(a) For global impacts, global warming is relevant, and the methodology enjoys a high degree of consensus at the midpoint characterization of chemical emissions. The need to address temporary carbon storage and sequestration was identified. Ocean acidification was mentioned as one of the main drivers for biodiversity loss. Being directly correlated to CO_2 emissions, there is less urgency for developing a midpoint impact category indicator for ocean acidification. The success of the Montreal protocol makes stratospheric ozone depletion less relevant as the magnitude of impacts has been largely mitigated.
(b) For other human health impacts, the effects of particulate matter emitted indoors and outdoors are major contributors to the burden of disease and a good candidate category to start with. Other human health impacts, including ionizing radiation, may be addressed in a second stage. Additional efforts are needed to integrate occupational health, injuries, noise and dietary risks in LCA, which are also important causes of human health effects.
(c) For impacts from resource use, the use of land and water causes several different impacts. The description and modeling of the complete set of pathways may be challenging. Land use is a major driver for biodiversity losses, and harmonization may first focus on this impact pathway, while recognizing that there are various ecosystem services which may be equally important but are not being addressed at this time. Energy resources are considered a good candidate for the second stage, whereas biotic and mineral resource depletion requires further framing to proceed towards harmonization.
(d) For other ecosystem impacts, eutrophication, acidification and ecotoxicity are major drivers for biodiversity loss and highly relevant for agriculture processes. Terrestrial acidification and freshwater eutrophication and ecotoxicity are potentially good candidates for harmonization and consensus building. Harmonization work may start now, but its final outcome is targeted for stage 2. Invasive species have a high environmental relevance but first require further framing for LCIA.

The extensive discussion that followed the initial presentation of potential priorities led to the following recommendations:

- In order to address major environmental effects in priority, the consensus-building process should start with highly relevant impact categories such as global warming, health effects of particulate matter emissions, land use and water use.
- Consensus on these can be reached by focusing first on selected pathways for which there is common agreement, e.g. for biodiversity impacts due to land occupation.
- Earlier LCIA work carried out within the SETAC-UNEP Life Cycle Initiative, such as USEtox and WULCA (water use in LCA), should be used as a starting point for further improvement. The harmonization efforts with regard to water use will be performed in conjunction with the WULCA working group (www.wulca-waterlca.org).
- Table 1 summarizes the initial candidate set of impact categories to be addressed within the two distinguished periods 1 and 2 of this flagship project. The selected indicators are not meant to be exhaustive and may be complemented in the future.

The following statements expressed by a few participants during the discussion on selecting impact category indicator candidates are noteworthy:

- Radioactive waste and ionizing radiation are considered important topics by Brazilian, French and Japanese scientists, considering that the electricity mix in some countries is heavily dependent on nuclear power.
- One participant argued that photochemical oxidation is more frequently applied by current users, compared to health effects of particulate matter, admitting though that according to the global burden of disease, particulate matter has a higher impact.
- One participant asked to consider the reversibility of environmental impacts when selecting impact category indicator candidates.

2.3 Feedback on impact categories from stakeholder workshops

The tentative list of impact categories and the rationales behind their selection has first been validated with a larger stakeholder audience taking advantage of multiple existing conference events worldwide and by teleconferences. A feedback form was also made available at http://www.lifecycleinitiative.org/ to provide additional individual feedback online.

These additional stakeholder workshops were held in conjunction with the LCA AgriFood Asia Conference, in Bogor,

Table 1 Initial working set of impact categories and their relevance to the three most common areas of protection, expressed as an x for first priority and an (x) for second priority

Stage	Impact category	Human health	Biodiversity	Resources/ecosystem services	Cross-cutting
1	Global warming (focusing on midpoint characterization)	x	x	x	Integration
1	Primary and secondary particulate matter (incl. PM indoors)	x	(x)		
1	Land use (initially focus on land occupation impacts on biodiversity)	(x)	x	(x)	
1	Water use (may only cover part of the impact pathway)	x	x	x	
2	Human toxicity (incl. indoor)	x			
2	Acidification, eutrophication and ecotoxicity		Starting with terrestrial acidification, freshwater eutrophication and ecotoxicity	(x)	
2	Energy resources	(x)	(x)	x	

Indonesia, in June 2013, with the ISO-UNEP/SETAC Water Footprint Training Courses in Gaborone, Botswana, in June 2013 and in Bangkok, Thailand, in July 2013, with the 8th Life Cycle Conference in Sydney, Australia, in July 2013, with the SETAC Europe Annual Meeting in Gothenburg, Sweden, and with the LCAXIII North American conference in Orlando, USA, in October 2013. Participants supported the proposed future direction of the Flagship project. Main conclusions are as follows: (a) the priority setting proposed in Table 1 is considered appropriate by a majority of respondents, especially the inclusion of work on water and land use impact assessment, which are both considered to have high environmental and end user relevance, (b) the selection of the topic energy resources is explicitly supported, (c) discussion is needed about consistently framing the areas of protection, (d) there is a need to provide a consistent framework and guidance to establish consensus on other impact category indicators such as effect of ionizing radiation, (e) increasing regional diversity of researchers/experts is essential, (f) endpoint approaches are primarily useful to compare the respective importance of midpoints and put them in perspective based on common metrics—rather than aggregating results in a single number, (g) the steering committee of the flagship project will enable the involvement of stakeholders from industry, academia and government from various continents, complementary to the work of experts involved in the task forces.

2.4 Cross-cutting issues

While much of the above focuses on providing specific recommendations for specific impact categories, the Glasgow workshop also emphasized the strong need to continue research and development on the LCIA framework and integrative issues. As an example, there is no currently accepted guidance on sensitivity analysis, normalization, valuation, determination of significance or communication of results and transparency. It is therefore important that individual indicators are consistent and integrated in a comprehensive framework. Agreement was reached in Glasgow on the following points:

- The flagship project will establish a guidance document on how to best reach consensus, ensuring consistency of indicator selection process and assessment approaches across impact categories. Building on earlier LCIA consensus work in the Life Cycle Initiative, focus is to reach consensus in midpoint indicators first, while positioning and relating these indicators within a consistent midpoint–endpoint framework. Midpoint approaches are more mature for most impact categories, hence the main focus of the consensus building on addressing these. As useful complementary information to ensure integration in a consistent midpoint–endpoint framework, each category specific task force will be asked to describe how midpoint indicators qualitatively or quantitatively relate to common and consistent endpoints across categories.
- The interface between inventory and impact assessment indicators needs to be analysed, with identification of both possible short-term solutions and rules to link LCIA indicators to current main LCI databases and longer term data requirements.
- Trade-off analyses across impact categories are necessary since mitigation of impacts in one impact category can lead to impact reduction or increase in other impact categories as well and provide co-benefits or co-damages in other areas of protection.
- This flagship project of the UNEP/SETAC Life Cycle Initiative will create global guidance on LCA-based footprints, like water or biodiversity. Footprints could also possibly be used to communicate results on indicators or groups of indicators.

Cross-cutting work on integration was initiated during a mini-workshop[1] in Cincinnati, Ohio, in May 2013, simultaneous to the Glasgow workshop. One focus of this workshop was on the role of normalization in various applications.

3 Evaluation criteria for selecting indicator approaches

Building on earlier work from the Life Cycle Initiative LCIA program and its extended version within the ILCD Handbook (Hauschild et al. 2013), an evaluation process based on predefined evaluation criteria will be applied consistently across categories to identify practices that are scientifically defensible, relevant to the decision endpoints and important, practical and acceptable for stakeholders. The evaluation process starts by drawing a ***diagram*** of the general impact mechanisms and describing the relevant pathways and flows, which may be part of a characterization model for the considered impact category. This step is necessary to improve transparency and to make explicit how methods represent known impact mechanisms.

Candidate characterization methods and models are selected and systematically qualified through a method-performance comparison, which evaluates them against a list of criteria covering (a) environmental relevance, (b) completeness of scope, (c) scientific robustness and certainty, (d) transparency and reproducibility, (e) communicability, (f) coherence and comparability, (g) data availability, data quality and ease of implementation and (h) timeliness and stakeholder acceptance. The general criteria are supplemented by a limited number of additional category-specific sub-criteria for 'environmental relevance' and 'scientific robustness and certainty' to reflect the mechanisms and pathways specific to the impact category as identified in the ***diagram*** of pathways and flows. A quantitative comparison of characterization factors will then be carried out on a subset of selected methods, enabling the identification of the key differences and aspects that are important in the impact category. This will serve as a basis for the consensus building process, which may either select elements of existing methods or build a new approach to achieve consensus.

4 Work process and next steps

For each impact category of stages 1 and 2, the process will include the following eight steps: (a) *Establish task forces:* The task forces for the different impact categories will start by a kick-off meeting in Fall 2013. We expect that active working group members will participate at least 8 days work per year and regularly attend teleconferences and meetings. Persons who are interested in participating as full or agenda members are invited to fill in the Expression of Interest form at http://www.lifecycleinitiative.org/. (b) *Identify experts.* In the Expression of Interest form, please add your suggestions of experts to invite for each selected category. (c) *Frame meetings:* We will obtain inputs from specialized domain experts on the proposed assessment framework in each impact category. (d) *Compare models:* The identified models will be assessed against the above evaluation criteria, comparing the characterization factors of a subset of selected models and fast-tracking the analysis for pre-existing consensus results (e.g. USEtox). (e) *Collect feedback:* At the SETAC Europe Annual Meeting 2014, the first workshop will share results of the method comparisons as well as the analysis and selection of models or model elements to represent the consensus. (f) *Build consensus and refine approaches.* In year 2, task forces will prepare a report proposing the assessment framework, as well as the selected models and factors as an input to, a technical workshop. (g) *Hold Pellston or other technical workshop*[2] *in 2015*: Participants will analyse the inputs from the established task forces, establishing consensus on LCIA approaches and factors for the first set of impact categories. (h) *Make recommendations and publish:* As a follow-up from the technical workshop, we will formulate recommendation on use, interpretation and limits of the approaches and publish these in scientific journals.

Although work on the second set of impact category indicators may begin earlier, the first Pellston workshop in 2015 will be dedicated to first stage indicators. For example, terrestrial acidification and freshwater eutrophication work will start in 2013 but will be addressed in a second Pellston interactive workshop in 2017, together with human toxicity and energy resources.

Integration task force A full-day workshop on the integration of LCA and LCIA in environmental decision making was held in Nashville, Tennessee, in November 2013 at the SETAC-NA annual meeting. A roadmap was developed which provides a better picture of the current state-of-the-research in this area as well as recommendations for future research. This will be a useful input to future work on integration that will be

[1] The mini-workshop was held in conjunction with the International Symposium of Sustainable Systems and Technology (ISSST), on 16 May 2013 (http://issst2014.net/).

[2] A Pellston workshop is an intensive, week-long event format developed by the Society of Environmental Toxicology and Chemistry (SETAC) in the 1970s. Each of the more than 50 such workshops held to date has adhered to the same structure, format and ground rules. Among these are the requirements that each of the invited participants agrees to engage as an individual expert, not as a representative of an organization, participate for the entire duration, contribute to a major publication derived from the effort and respect the consensus-building process employed during the conduct of the workshop. SETAC Pellston workshops have produced seminal publications across a variety of environmental science topics and issues, including five such publications on LCA.

carried out by an additional cross-cutting task force of this flagship project.

Acknowledgments The authors acknowledge the contributions from the participants of the Glasgow workshop and the UNEP/SETAC Life Cycle Initiative for funding this activity.

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